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POTENTIAL APPLICATIONS OF ADVANCED AIRCRAFT IN DEVELOPING COUNTRIES

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POTENTIAL APPLICATIONS OF ADVANCED AIRCRAFT IN DEVELOPING COUNTRIES

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SUMMARY

Air transportation concepts for movement of cargo in developing countries are reviewed using aircraft which may appear in the future. For certain industrial applications including mining and forestry, the relative costs of doing the job using different types of aircraft are compared with surface transportation systems. Two developing countries, Brazil and Indonesia, were taken as examples to determine what impact they might have on the aircraft markets of the future. Economic and demographic data on developing countries in general, and Brazil and Indonesia in particular, are reviewed. The concept of an industrial city in a remote area developed around an airport is discussed. It is noted that developing areas generally lack extensive surface transportation systems and that an air transportation system can be implemented in a relatively short time. A developing nation interested in rapid expansion may thus find the role of air cargo far more important than has been true in developed nations. Technological developments which may dramatically increase the performance of agricultural aircraft are also reviewed.

INTRODUCTION

In 1975, the developing countries* of the world produced approximately \$607 billion** in Gross Domestic Product (GDP), or 21 percent of the world's GDP (fig. 1). By the year 2005, these same countries could increase their share of world product to approximately 32 percent (3500 billion**). Such a dramatic increase in economic growth and purchasing power, coupled with the relatively poor surface transportation systems that exist in many developing countries, suggests that these nations may offer great opportunities for the world's aviation industry. In the past, developing nations have tended to favor surface transportation investments over air because of factors such as conservation of foreign exchange, a relatively unskilled work force, availability of road building supplies, and the creation of local employment which road construction generates. In the future, such nations may develop special aircraft requirements which so far have not emerged because of their relatively small economic base. Therefore, developing countries may have an impact on the design and technological content of some future aeronautical products.

The National Aeronautics and Space Administration (NASA) has the primary governmental role in developing new aircraft technology for the United States and so is interested in the role which developing countries might play as a future market for advanced technology aircraft. Examples of future aircraft whose design might be affected include not only conventional takeoff and

*A developing country is defined as having under \$3000 per capita annual income (certain low-population oil-rich states are exceptions).

**1970 dollars.

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landing (CTOL) subsonic jet passenger aircraft but also advanced aircraft of other types. Examples include cargo airplanes, helicopters, short takeoff and landing (STOL) vehicles, and airships. In 1975, a NASA review of the pertinent literature found that although a voluminous amount of data were available on developing countries, little information existed on the long-term role which aircraft might play in the general development of transportation systems and in the natural resource exploitation of developing countries. Even less was available on the impact which advanced aircraft might have on overall economic development.

With this background in mind, the NASA decided to sponsor a comprehensive long-term look at this entire subject (fig. 2). The year 2005 was chosen as the study's end point.

APPROACH

The basic work was done under contract by United Technologies Research Center (UTRC) who subcontracted part of the work to the consulting firm of Parsons, Brinckerhoff, Quade and Douglas (PBQD). UTRC was responsible for the management of the overall effort, for detailed data gathering and analysis, for generation of demand, traffic, and economic forecasts, and for the computer programs used in the analysis of the aircraft and surface cost comparisons. PBQD did much of the analysis associated with estimating surface transportation and road construction costs in developing countries (a very specialized field). The approach taken is shown in figure 3.

Initially, much time was devoted to organizing and reading a large amount of information on economic growth prospects, demographics, and aviation background gathered from comprehensive library searches or collected by the NASA beginning in 1975. A complete description of the work done is given in reference 1. Extensive work done on passenger aircraft in this study has been omitted from this paper. Reference 1 also includes a bibliography of over 270 pertinent references, and is perhaps the most extensive ever compiled on this subject.

As defined in this paper, developing countries include approximately 125 nations. It was clearly impractical to look at all such countries. Therefore, it was decided to carefully select two representative countries for detailed case study and analysis.

Initially, the candidate list of developing nations was narrowed to 30 possible study countries. A more detailed look at the information available, including its accuracy and reliability, narrowed the list to 10 candidates, for which additional data were obtained. After much consideration, two countries were selected for detailed case-study and analysis (see section on Developing Country Selection Factors for the rationale used). These two study countries were then analyzed to see how their economic growth might be accelerated through the use of air transport. In doing this, potential traffic growth, airplane requirements, and types of airplanes needed were estimated.

The airport-industrial city concept (ref. 2) advanced by E. N. Hall of United Technologies was also included. This concept envisions the growth of manufacturing and processing industries around a relatively small, possibly isolated, city located near abundant natural resources but without an extensive surface transportation system to use in developing these resources. Costs and benefits of using aircraft to develop new industries were estimated and compared to surface transportation systems where possible. Based on these results, recommendations for aeronautical research requirements were made.

DEVELOPING COUNTRY TRANSPORT NEEDS

In reviewing the needs which developing countries might have for an air cargo transportation system, four possibilities were considered (fig. 4). The first is the development of a new natural resource which is presently untapped or inaccessible. The second is the attempted tapping of an uncertain, potentially lucrative, market area that is accompanied by great political or social risks which jeopardize the initial investment (a common drawback to large-scale financial undertakings in developing countries). The third case, in which a more-productive and lower-cost transport system based on air replaces or supplements an existing surface transport system, is a possibility where certain factors such as difficult terrain are present. The fourth possibility occurs where existing surface transport modes have proven unsatisfactory (for various reasons including lack of competition) and a large-scale service improvement is needed (possibly obtained by quicker delivery of goods). In the studies described here, air transport appears to offer potential advantages in all four of these market areas.

This paper will concentrate on specialized aircraft for movement of cargo including payloads such as construction equipment and supplies, commodities, multi-purpose utility missions, and agricultural applications involving a wide variety of industries (fig. 5).

DEVELOPING COUNTRY SELECTION FACTORS

Most developing countries are clustered around the equatorial region (fig. 6). The resulting climate is thus usually hot and either dry all year, wet all year, or wet and dry depending on the season. Therefore, it was decided that the study countries selected should have a climate representative of these patterns.

The potential economic strength (ref. 3) of the candidate countries was a very important consideration. Natural resources such as major deposits of minerals, extensive forest area, and land suited for agriculture and grazing, all help lay the foundation for sustained economic growth. In addition, a substantial (but not excessive) population base can provide the demand for goods and services which lead eventually to increased aircraft requirements. Brazil, with a population of 110 million in 1978, and Indonesia, with 135 million people, provide the kind of residual population demand needed to sustain domestic growth and still offer opportunities for a major growth in export products.

Brazil's policy of rapid domestic expansion, coupled with its large land area (comparable to that of the United States (fig. 7)), has caused the government to emphasize the development of its air transportation system. Indonesia's traditional means of transport has been water (ref. 4). With its population divided by ocean and dispersed over an area greater than the contiguous United States, Indonesia finds that air transport not only shrinks distances but can also help unify a country composed of many different ethnic backgrounds. Factors such as significant distances between major cities and basic social desires help create a demand for airplanes which can only accelerate in countries such as these.

Such considerations, along with a detailed review of past economic growth areas and a judgment of what is likely to happen in the future, led to the final selection of Brazil and Indonesia as the case study countries.

Estimates of future growth in gross national product are included in figure 8, which shows a 7-fold growth for Brazil and a 9-fold growth for Indonesia over the 31 year time period shown. Projections over this length of time must, of course, be viewed with caution. However, these estimates were made after reviewing and consulting with knowledgeable individuals from organizations such as the World Bank, United Nations, several major New York banks (with large investments in the study countries), and numerous other sources. Also included in figure 8 is an estimate of likely air cargo traffic growth in the study countries. The sharp drop in domestic shipments during the late sixties is the result of revolutions that took place in each country. Although domestic growth suffered greatly under such conditions, international traffic continued to expand rapidly, perhaps indicating the inherent economic strength of these two countries.

CONCEPTS FOR USING ADVANCED AIRCRAFT TO BUILD INDUSTRIES

Undeveloped natural resources are a main characteristic of some developing countries. Another main characteristic is the relatively short and unimproved nature of many airport runways. Aircraft concepts (fig.9) considered as a likely means of building new industries under these conditions include helicopters, short or reduced takeoff and landing aircraft, airships, and agricultural airplanes. A large cargo airplane, operating from an airport of international quality, is another means of speeding development in many industries. Ventures which seem particularly ripe for using such aircraft include mining industries such as copper and aluminum, petroleum exploration, pipeline and road construction, forestry and associated wood products, high value-added manufacturing, and agricultural products.

To evaluate the benefits of using air transportation for such work, a cost model (see ref. 1 for description) was developed which includes provisions for competing both existing and advanced* aircraft against alternative surface transportation systems. This cost model was the main tool used to evaluate the

*much of the advanced technology which might be used on future aircraft was reviewed in reference 5.

industrial development potential of advanced aircraft on a consistent basis and was used extensively in the course of the study. The following sections will review some of the specific aircraft studied.

Helicopters. - Existing and advanced helicopters offer much promise for an industry such as remote mining development. Future production aircraft may result from current research helicopters which include the Army-Boeing Vertol Heavy-Lift-Helicopter (HLH), the Rotor Systems Research Aircraft, and the Tilt-Rotor Research Aircraft.

To look at the increased capability which production versions of such vehicles might offer, it is instructive to review a recent major copper mining industry developed in Indonesia, the Ertsberg copper mine, dedicated in 1973 by Freeport Indonesia, Inc., a subsidiary of Freeport Minerals Company, an American firm based in New York.

The Ertsberg (fig.10(a)) is a 29.96 Tg. (33,000,000 tons) deposit of material of which approximately $2\frac{1}{2}$ percent is copper, possibly the largest outcrop of base metal in the world (ref. 6). It is located in one of the most remote regions on earth (fig. 10(b)), about 120 km. (74.6 st. mi.) inland through mangrove swamp, rain forest jungle, and mountain terrain on the West Irian island of Indonesia at an elevation of over 3400 m. (11,155 ft.). The mountain containing Ertsberg drops a precipitous 560m. (1837 ft.) into a chasm at the mountain's base.

To develop the copper deposit, it was decided to construct a seaport, a road to the Ertsberg, a pipeline for moving copper slurry out, preliminary processing mills, and a 1463m. (4800 ft.) aerial tramway. The problem was to do this at minimum investment cost and in the shortest possible time. The solution was to use Bell model 204B ((approximately 1814 kg. (2 tons) sea level lift capability) helicopters to haul the personnel and equipment to staging and camp areas in the jungle from which base and road construction could begin. An expenditure of over 175 million dollars was required.

Beginning in 1969, single individuals were dropped from helicopters into the jungle. These men cleared spaces for the helicopters to land, sometimes using felled trees for a landing pad. From such clearings, prefabricated tent-camps, brought in by helicopter, were constructed enabling large-scale construction efforts to begin. D-4 and D-6 Cat tractors, front-end loaders, dump trucks, lumber, cement, etc. arrived by helicopter for road-grading and campsite operations. The high altitudes together with the relatively small lift capability of the 204B meant that tractors had to be moved in pieces and then reassembled in the field (ref. 7). One D-6 Cat required 32 helicopter trips to deliver it to an altitude of 3400m. (11,155 ft). This time-consuming and costly procedure could have been avoided had much bigger helicopters such as an HLH ((with 31.76 Mg (35 tons) sea level lift capability)) been available.*

*An artist's concept illustrating use of a large helicopter to develop Ertsberg is given in figure 10(c).

Trucks were initially unable to climb some of the steep road grades. They were pushed by tractors up slopes so rough that after completion of the trip, the steel-belted radial truck tires had to be replaced.

The 204B helicopters hauled all supplies and equipment ((approximately 27 Gg. (30,000 tons)) for over 4 years until the road was sufficiently complete that trucks could handle the really high volume of supply movements ((163 Gg. (180,000 tons)) needed to complete project construction (figure 11).

The cost model previously mentioned was used to compute the relative financial returns from doing this project using alternate means of transportation. Study aircraft included S-64 Sikorsky Skycrane helicopters ((about 9.07 Mg. (10 tons) sea level lifting capacity)), a combination of S-64's and trucks, a heavy-lift airship, a heavy-lift helicopter, a C-130 H, and an advanced STOL airplane. A sample of the results obtained is given in figure 12, where the Ertsberg project (using the 204B helicopters and trucks) corresponds to a distance of 120 km. (74.6 st. mi.) on the "base case" curve. These results show all of the advanced aircraft offering better returns on the study company's equity than the 204B helicopters used in developing Ertsberg, basically because the greater lift capability of the advanced aircraft permits both lower operating costs and construction times which are years shorter in some cases. The advanced aircraft also have the advantage of enabling the project to begin generating revenue much earlier, a factor of great importance when evaluating the discounted cash-flow return from a project requiring a long-term major initial investment. Figure 12 also shows that as inland distance increases, the advantages of a STOL airplane become overwhelming for a project of this size, and would justify construction of the short landing strips required.

Multipurpose STOL Aircraft. - The Air Force Advanced Medium STOL Transport (AMST) competition between Boeing's YC-14 (with over-the-wing blowing) and Douglas's YC-15 (with an externally-blown flap) has resulted in the development of advanced flight cargo vehicles (ref. 8, 9) with both the short-field and rough runway performance capability so useful in developing countries (fig. 13). The military requirement for flexibility in carrying personnel as well as cargo is also extremely useful in this application because developing countries often require low-density passenger transport (ref. 1).

An example of the kind of transportation flexibility available with STOL aircraft is given in figure 14. Only about eight percent of Brazil's airports have paved runways. This indicates significant market potential for a low-cost STOL transport which does not require a major investment in improved ground facilities and the other infra-structure support required for an international or a major national airport. Potential for such aircraft also exists in Indonesia which, despite its dispersion over a vast area, has only 67 airports (of which but 14 are paved). Under such conditions, STOL aircraft offer the possibility of a basic transportation system with which to develop interior areas in a rapid and timely manner.

Figure 15 shows a major earth road and some surrounding countryside in the Brazilian interior. Such terrain provides a low-cost and flexible intermodal transfer mechanism between interior surface freight vehicles and

STOL aircraft with rough field capability. Mountainous terrain for which long runways are impractical would also become more accessible with the STOL capability. Connections with other parts of the entire Brazilian nation are possible as well as links with surrounding population centers of other South American countries within the range of STOL aircraft. The STOL technology developed during the AMST program may eventually prove extremely important as the developing country aircraft market grows.

The economics of a STOL configuration for a remote mining type mission were given in figure 12 and appear attractive for a wide range of inland distances. Many other utility missions for STOL airplanes have been identified, including moving loads outsize to the C-130, heavy lift missions, and emergency disaster relief.

Airships. - The ecology of the tropics is surprisingly fragile. Strip forestry as practiced in the United States can easily lead to soil destruction in tropical areas. Monsoon rains leach the soil and render it unsuitable for future use. Thus, the airship may be useful for selective forestry applications given its ability to both hover and to lift very heavy loads without environmental damage. Tropical forests such as those in Brazil contain a wide variety of hardwoods, some of which are very valuable. Official government estimates of the end product value of the hardwood in the Roraima area of Brazil alone exceed 17 billion dollars. Balloons are already used in forestry applications in various parts of the world, and an English firm is now building airships for Venezuelan use in timbering.

Airship designs can reach enormous payload sizes (ref. 10-12). A 8160 kg. (9 ton) hardwood tree three feet in diameter and 50 feet long can be easily lifted by an airship. In some applications, individual logs harvested by airships could be collected at staging areas and then loaded directly onto ships bound for major processing ports (fig. 16). In other cases, logs might be lifted to Brazilian sawmills for further processing into lumber or other higher value products (i.e. furniture) suited for movement by other means of air transportation. Using an airship for harvesting tropical forests eliminates costly logging roads, feeder roads, surface vehicles, and the accompanying environmental damage which would occur with a surface transport network.

To evaluate this application, the economics of the airship were compared to other means of selective forestry harvest. Some results are given in figures 17(a) and 17(b) as a function of volume of output (in thousands of cubic meters) for two different yields (harvest per area). At a typical yield of 12.8 cubic meters per hectare (183 cu. ft. per acre), the airships show lower harvesting costs than the helicopters used in the study but the surface system offers the lowest cost at any level of output. In the very selective low yield case, however, 1.6 cubic meters per hectare (22.9 cu. ft. per acre), the results are a little different (fig. 17(b)). At this low volume level, a small airship could offer lower cost as well as less ecological damage.

Additional cost comparisons using other types of aircraft to develop different industries showed similar trends. For example, a road-based system was more economic when very large volumes were moved over short distances, and

the air mode was often superior when smaller volumes were transported over longer distances.

Large Cargo Aircraft. - It is possible that large cargo aircraft (refs. 13, 14) can also be useful in stimulating the economies of developing countries by increasing the growth of foreign trade. Airplanes and airplane concepts for doing this include existing wide-body aircraft like the Boeing 747F freighter, a proposed large-volume double-lobe fuselage configuration from the Boeing Company, a conceptual joint military-civil cargo aircraft called the C-XX, and the futuristic span-distributed load configuration in which the weight of the cargo is used to balance the aerodynamic loads in flight (fig. 18).

These very large aircraft, when combined with a custom-made ground support system, offer major reductions in both airplane direct and indirect operating cost (ref. 13). The recently completed NASA-sponsored Cargo/Logistics Airlift System Studies (CLASS) (refs 15, 16) by Douglas and Lockheed have looked at the world-wide freight market growth that might result from a reduction in total operating cost of 30-35 percent which may be possible for this type vehicle. Figure 19 shows the variation in direct operating cost which occurs for several large cargo designs. For gross weights under about 454 Mg. (1,000,000 pounds), conventional-type airplanes appear most economic.

The right side of figure 19 shows a main benefit of a spanloaded configuration. The simplified cargo loading and unloading possible with this design offers major reductions in handling cost and improvements in productivity, but also requires specialized ground equipment. To date, the spanloader configuration has not found a market niche since the great productivity of the aircraft together with the limited market applications now foreseen would result in an unprofitably small production run.

Developing countries would not be the prime market for such aircraft but could at least provide a supplementary market. Using the gross national product and air cargo growth predictions made earlier, it appears that Brazil could need up to 47 large-cargo airplanes with a payload of approximately 177 Mg. (390,000 lbs.) between now and the year 2005 while Indonesia could need about seven (fig. 20). Preliminary results of the CLASS studies were available and were used in arriving at these estimates.

A factor which could help create the need for a large-payload cargo airplane is the adoption of the airport industrial city concept by both developing and developed countries (fig. 21). This concept could help speed the industrialization of internal, remote or landlocked areas. This is now happening to a limited extent in the Brazilian capital city of Brasilia.

The airport-industrial city concept was applied in the present study to the city of Santarem, Brazil, located at the confluence of the Amazon and Tapajos Rivers, about 1000 km. (620 st. mi.) inland from Belem (fig. 22). The city now has a population of approximately 140,000. The territory around Santarem has extensive natural resources including bauxite deposits, timber, grazing land, and hydroelectric power sites, all of which offer potential for major industrial development.

These industries were assumed to be developed. As one example, the value added in progressing from ore extraction, to primary metal manufacturing, to intermediate products, and finally, to finished goods was estimated for a case study of aluminum processing. From such work, the volume of freight which might pass through the industrial airport was estimated. Starting from an essentially zero base in 1980, it was found that by the year 2005, nearly 500 Mg. per day (511 tons per day) might be shipped through the Santarem airport, including products such as meat, leather, aluminum, wood, and paper (fig. 22).

Aerial Applications Aircraft. - In most developing countries, agriculture is the most important economic sector. These nations often devote a major segment of their labor force to agricultural production, yet still cannot supply enough food for domestic needs. To a large extent, this is a result of relatively primitive farming and distribution methods. An air cargo system which can transport harvests in a timely manner to needy areas has obvious value. Indeed, some areas of a developing country may go hungry, while stored crops (which could be quickly moved to remote areas by the aircraft previously described) rot in warehouses in more developed parts of the nation. However, developing countries also need increases in crop yield. One way to increase yield (for certain crops) is to increase both the use and performance capability of agricultural aircraft.

Fundamentally, an agricultural aircraft is an air cargo transport vehicle used to move fertilizer, seeds, pesticides, and other such goods from a loading area to a field where such products are needed. In a sense, the agricultural aircraft is a totally automated air cargo transfer and distribution system from the time the aircraft is loaded, since the cargo is not touched again even when finally put to its intended use.

Technological Development

Since 1976, the NASA has been developing a research program aimed toward major improvements in the performance of aerial application systems including both the aircraft and the dispersal mechanism. The NASA role in this work is presently envisioned as research into dispersal systems, methods, and capabilities as well as aircraft performance and safety.

The major problems now encountered with existing agricultural aircraft are minimizing chemical drift and obtaining a uniform spray distribution pattern of maximum width for a given airplane. These problems cause much waste of spray material and aircraft flight time, spray drift into neighboring areas and possible crop damage, lawsuits, intense environmental complaints, and strong governmental regulations. For certain chemicals, these regulations may predetermine an aircraft's speed, altitude, dispersal nozzle, and proximity to bodies of water. Atmospheric conditions may even prevent the flight itself.

Winglets, originally developed by Dr. R. T. Whitcomb of Langley Research Center with reduced energy consumption in mind, may offer promise for improved dispersal spray patterns because the vortex which trails behind each wing tip

is a major source of spray drift and uneven distribution. Winglets displace this vortex upward, reduce its strength, and could at least partially alleviate the problem. The concept is illustrated in figure 23. Flight tests and additional wind tunnel tests will be conducted to validate these expectations.

Regarding aircraft design requirements, the NASA has recently sponsored two agricultural aircraft system design studies. During these studies, Lockheed-Georgia (ref. 17) defined several advanced fixed-wing agricultural aircraft configurations and Bell Helicopter (ref. 18) studied a variety of rotary-wing configurations. One Lockheed configuration is shown in figure 24 and features twin turbo-prop engines with two separate ram air turbines to power the hopper dispersal systems. The objective of this work was to analyze the effects on mission productivity and economics of such agricultural aircraft design considerations as faster spray and ferry speeds, faster turn rates, increased payloads, use of composite materials, and advanced engines. Overall mission performance was analyzed over a wide range of material application rates and field sizes.

Safety efforts are now directed toward solution of high angle of attack stall-mush problems which cause approximately half of all agricultural aviation pilot fatalities. Segmented leading-edge high-lift devices will be investigated in both wind-tunnel and flight tests to analyze their potential for reducing an airplane's tendency for wing-drop or roll-off at the stall. A new aerial application capability may be possible as an out-growth of additional planned NASA studies which will evaluate new dispersal system concepts that allow high-volume application by air of dry materials (e.g. fertilizer) which are presently applied by ground equipment.

Adoption of the new technology described here may be impeded as a result of the fragmented aerial applications industry, the small amount of capital available for aircraft development, and the limited financial resources of the airplane operators. The NASA is therefore trying to keep all industry stakeholders advised on the progress of its agricultural program, through conferences which review the ongoing work and also by publishing formal reports which describe the results of its research. This work should help provide the technology which the aerial applications industry needs to meet the steadily increasing economic and environmental pressure for improved aerial application systems.

Many developing countries today have a favorable climate but lack one or more of the necessary elements for increased agricultural production (i.e. water supply, technology, transportation infrastructure, etc.). As these constraints are overcome, production should rise-dramatically in some cases.

EXPECTED FLEET PURCHASES

The work described here is limited to air-cargo type vehicles. Additional studies were also accomplished for passenger airplanes and for general aviation aircraft. Figure 25 summarizes this work as far as fleet purchases are

concerned through the year 2005. Both Brazil and Indonesia are seen to be significant markets for aircraft in this time period with tremendous purchases expected relative to the size of today's fleet. Greatest growth occurs for the all-cargo and general aviation industries. Large cargo aircraft purchases are included in the estimates for international all-cargo aircraft. When one considers that these aircraft purchase estimates are for only two developing countries, it appears likely that the prospects for increased air freight movement throughout the world are very great indeed.

CONCLUDING REMARKS

The present work indicates that air transportation can play an important role in the economic progress of developing countries. By the turn of the century, the rapid economic growth now occurring in many developing countries should result in a major redistribution of the world's income. Some countries now classified as "developing" will become "developed" and are likely to become far more important to the world's civil aviation industry.

Developing countries will be increasingly important buyers of conventional subsonic long-haul jet passenger aircraft but not to the point of significant influence on the design or technological content of future aircraft of this type. Such aircraft already operate daily out of developing country airports of relatively high quality (i.e. with regard to their air traffic control system, runway characteristics, and ground handling equipment). However, the technological content of more specialized aircraft may be influenced by developing country requirements and reflected in designs which fill a need related to specialized missions (e.g. short-haul, low-density, rough runways, natural resource development).

As one example of what an aircraft support system could do in creating new industries, Brazilian bananas sprayed by agricultural aircraft (using chemicals brought to the field by STOL airplanes) may someday be offered for sale in major international population centers the day after harvest, using STOL aircraft for initial transport and large cargo aircraft (which operate from regional economic centers based on the airport-industrial city concept) for long distance transport. Likewise, for products such as wood and aluminum, it is possible to visualize a variety of different aircraft being used at each stage of the production cycle. Successive processing operations increase value and make movement by air freight much more likely.

As with many important undertakings, a significant launch investment is needed to develop most of the aircraft described herein. Undeveloped industries lack the big project kick-off buyers who launch subsonic passenger aircraft. Thus, actual production aircraft may depend on an initial military order, additional market growth, and/or much greater initiative and risk-taking by aircraft manufacturers.

Some developing countries already are committed to a rapid advancement in their technological status and see the development of their own aircraft industry as a means of helping achieve technological and other national goals

(such as developing a more skilled labor force). Such nations are increasingly likely to compete with the United States and other manufacturers at the smaller end of the aircraft scale, where they can generate a domestic demand sufficient to justify a production line and yet still export aircraft products to both traditional and new trading partners.

In the future, aircraft manufacturers can be expected to find more frequent opportunities in developing countries.

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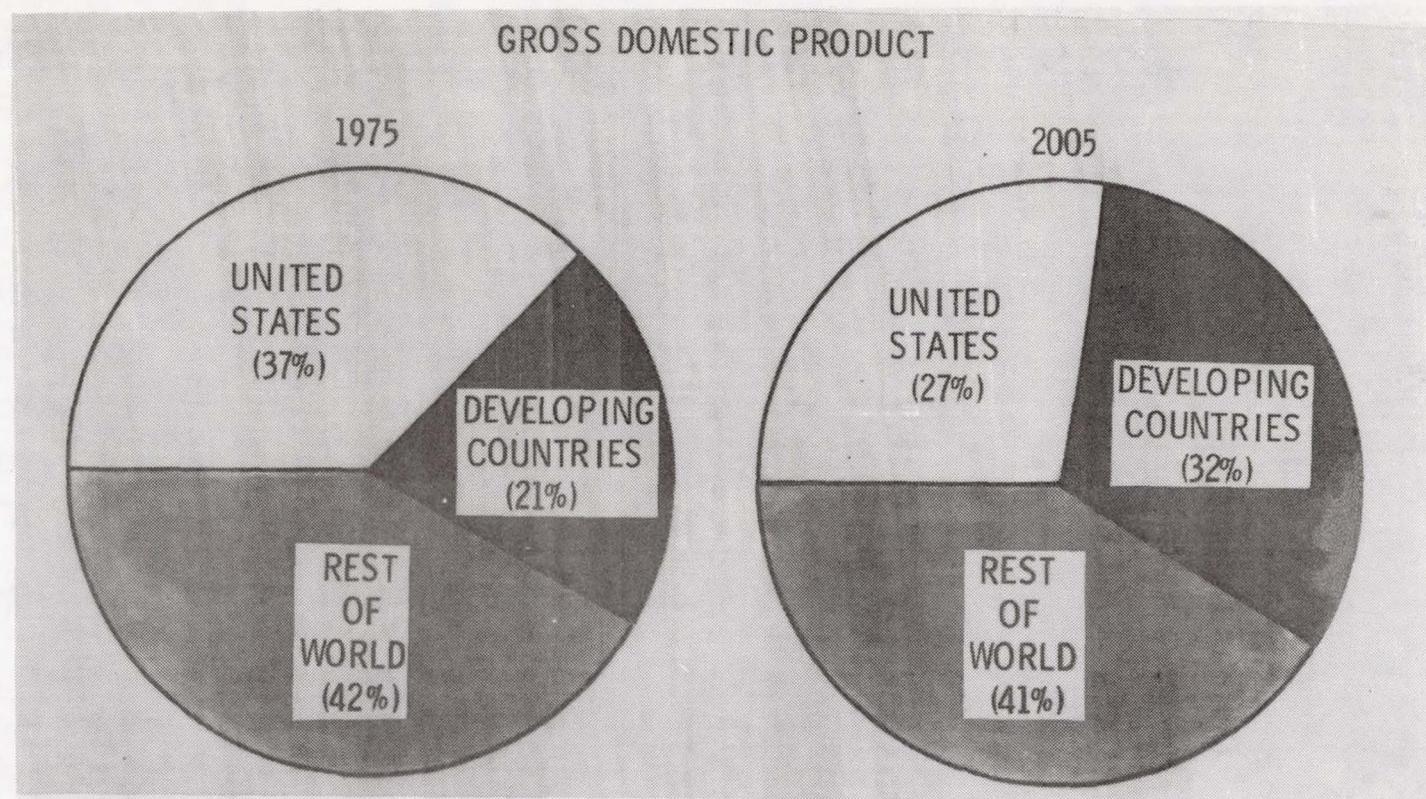


Figure 1.- Market importance of developing countries.

- TAKE LONG LOOK AT DEVELOPING COUNTRIES (1985-2005)
- USE AIRCRAFT TO DEVELOP ECONOMY FASTER
- FUTURE AVIATION ROLE
- IMPACT ON AIRCRAFT DESIGN (CONVENTIONAL, SPECIALIZED)
- DETERMINE EFFECT ON AIRCRAFT TECHNOLOGY REQUIRED

Figure 2. - Study objectives.

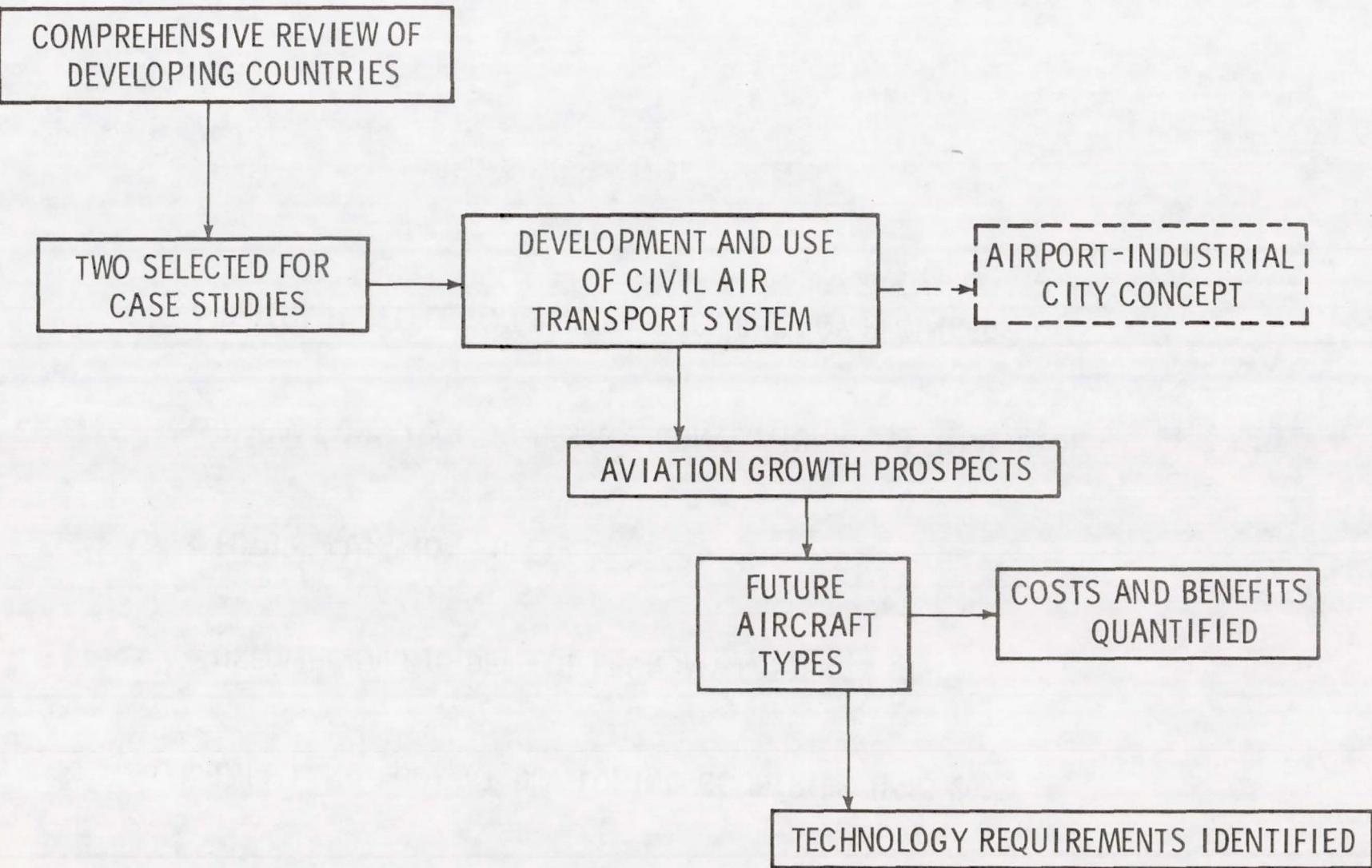
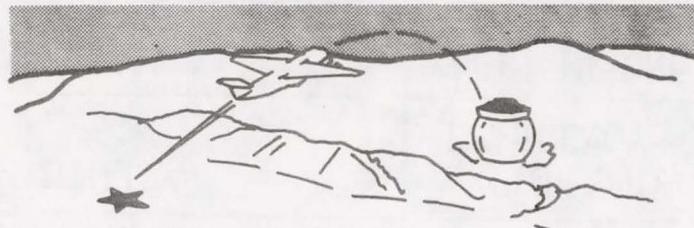
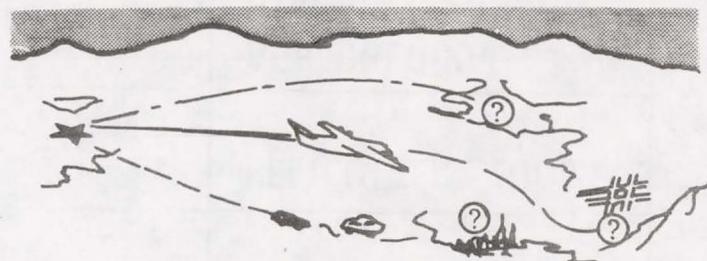


Figure 3. - Approach to developing country studies.

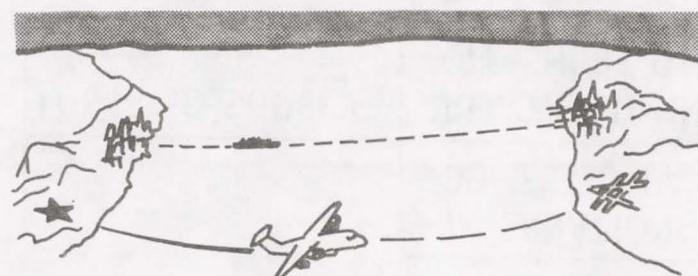
NEW MARKET (UNTAPPED OR INACCESSIBLE RESOURCE)



UNCERTAIN MARKET (MINIMUM INVESTMENT RISK)



PLANNED MARKET (LOWER-COST SURFACE MODE SUBSTITUTE)



IMPROVED SERVICE MARKET (REPLACE UNSATISFACTORY SURFACE TRANSPORT)

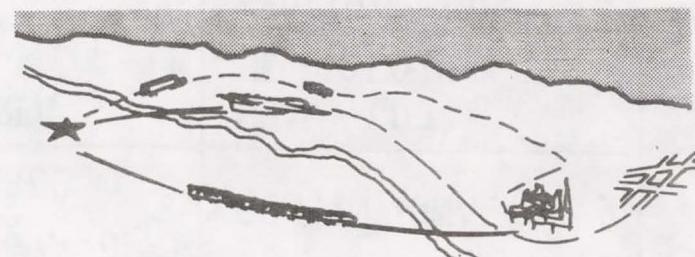


Figure 4. - Where air cargo can fill a developing country need.

PAYLOAD	SAMPLE APPLICATION	AIRCRAFT TYPE
CARGO (COMMON CARRIER)	INTERNATIONAL ALL-CARGO	LARGE CARGO
	DOMESTIC ALL-CARGO	CONVENTIONAL, STOL
	INTERNATIONAL PAX/CARGO DOMESTIC PAX/CARGO	CONVENTIONAL
LOGISTIC SUPPLY	REMOTE MINING AREA OFF-SHORE OIL	HEAVY-LIFT HELICOPTERS, STOL
COMMODITY MOVEMENT	FORESTRY AGRICULTURAL PRODUCTS MINING	AIRSHIP, STOL
CONSTRUCTION	PIPELINE POWERLINE	HELICOPTER, STOL
UTILITY	EXPLORATION EMERGENCY	HELICOPTER, STOL
AERIAL APPLICATIONS	AGRICULTURE FORESTRY	AGRICULTURAL AIRCRAFT, AIRSHIP, HELICOPTER

Figure 5. - Possible applications of cargo aircraft in developing countries.

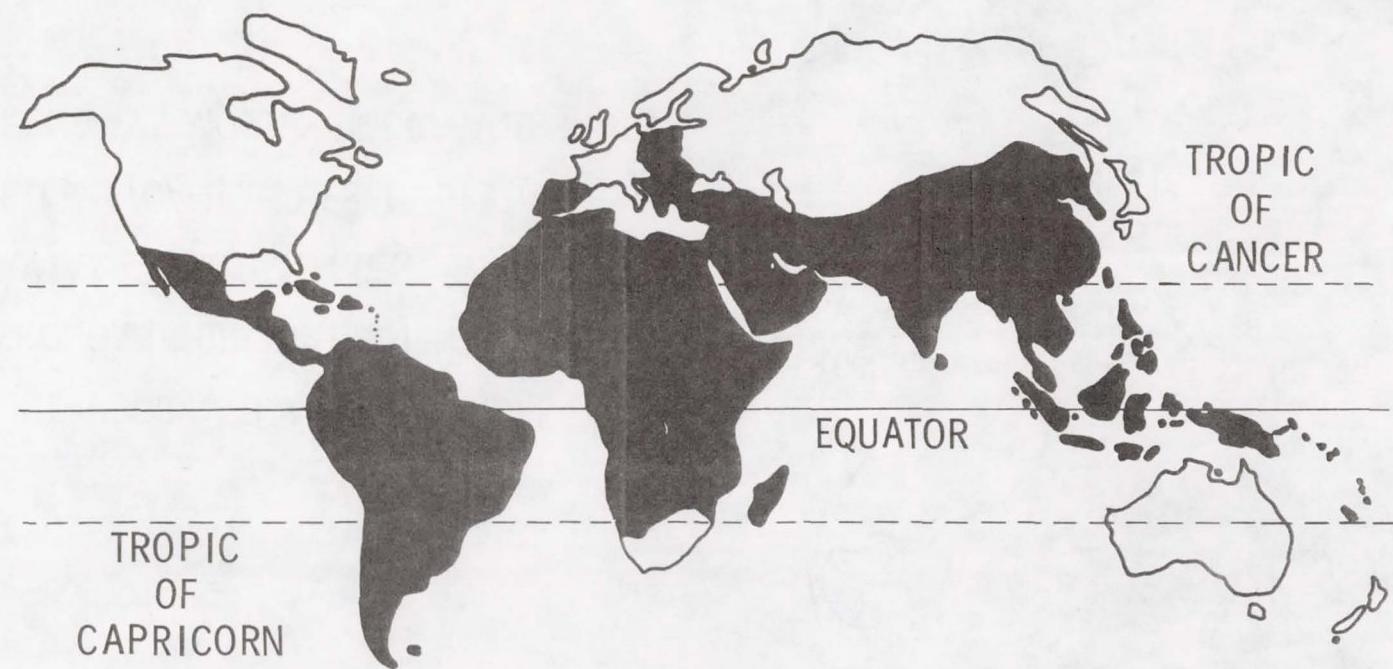


Figure 6. - Developing country locations.

- UNTAPPED NATURAL RESOURCES
- ECONOMIC GROWTH POTENTIALLY GREAT
- AVIATION COMMITMENT EXISTS
- SIGNIFICANT DOMESTIC DISTANCES
- RUNWAYS MOSTLY ROUGH AND SHORT

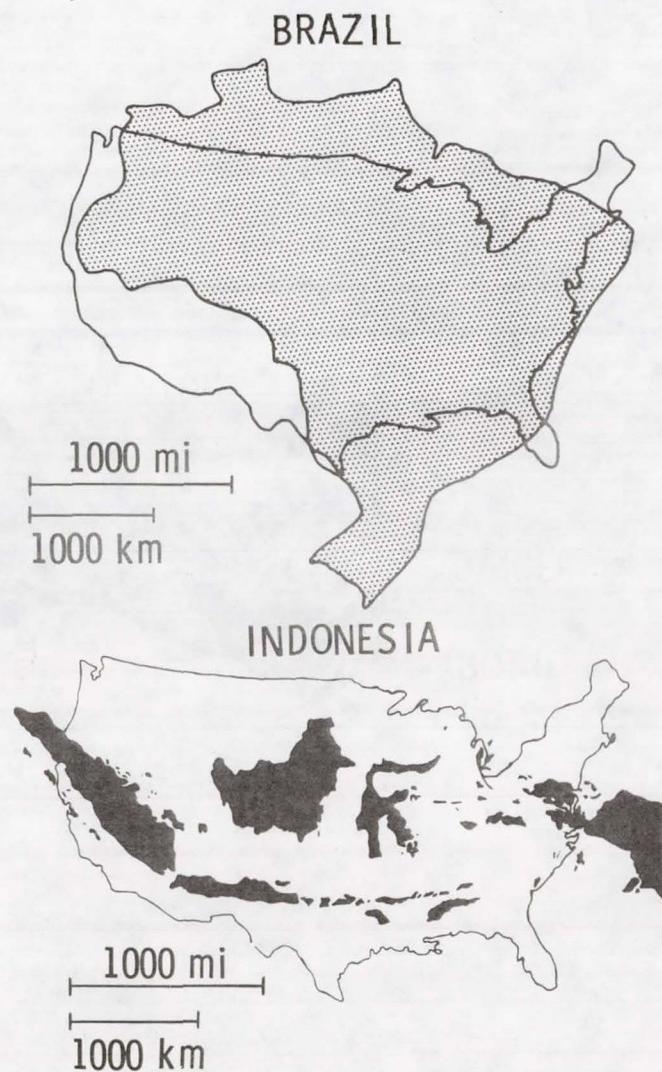


Figure 7. - Brazil and Indonesia selected for case studies.

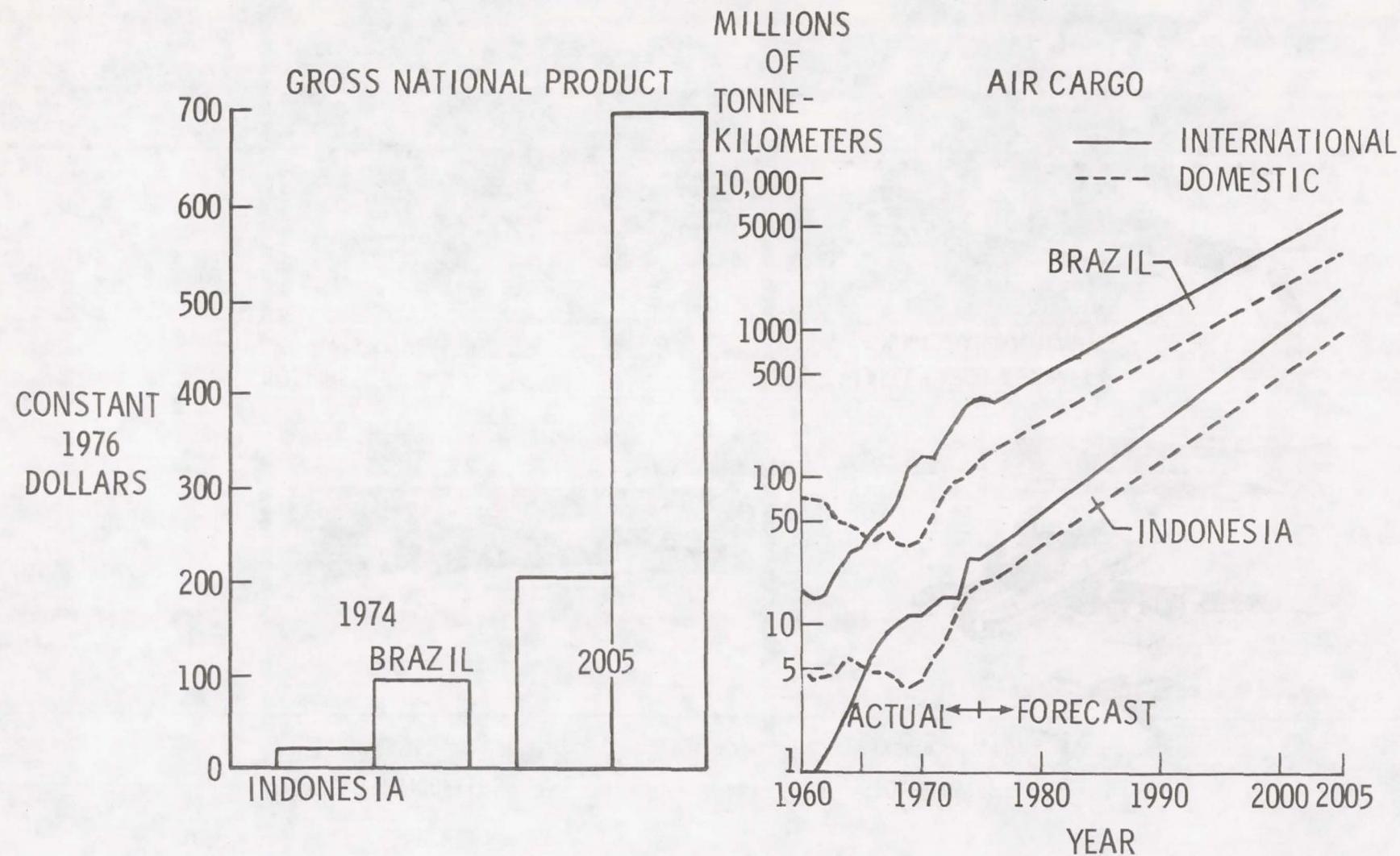
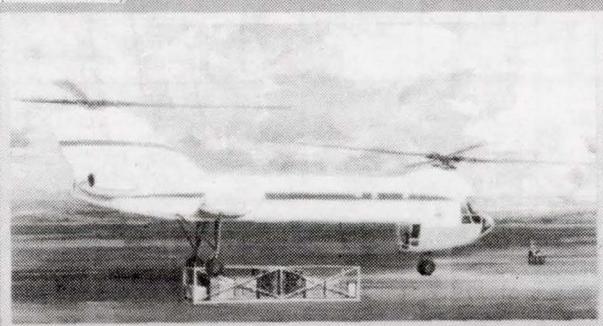


Figure 8. - Expected economic and air cargo growth in study countries.

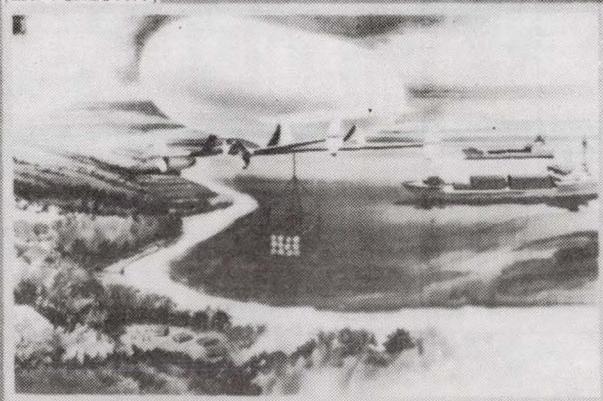
ADVANCED HELICOPTERS

[EX. MINING]



AIRSHIPS

[EX. FORESTRY]



STOL AIRCRAFT

[MULTIPURPOSE]



LARGE CARGO AIRCRAFT

[EX. INTERNATIONAL TRADE]



Figure 9. - Concepts for using aircraft to build industries in developing countries.



Figure 10(a). - Ertsberg - Birth of an Indonesian copper industry.

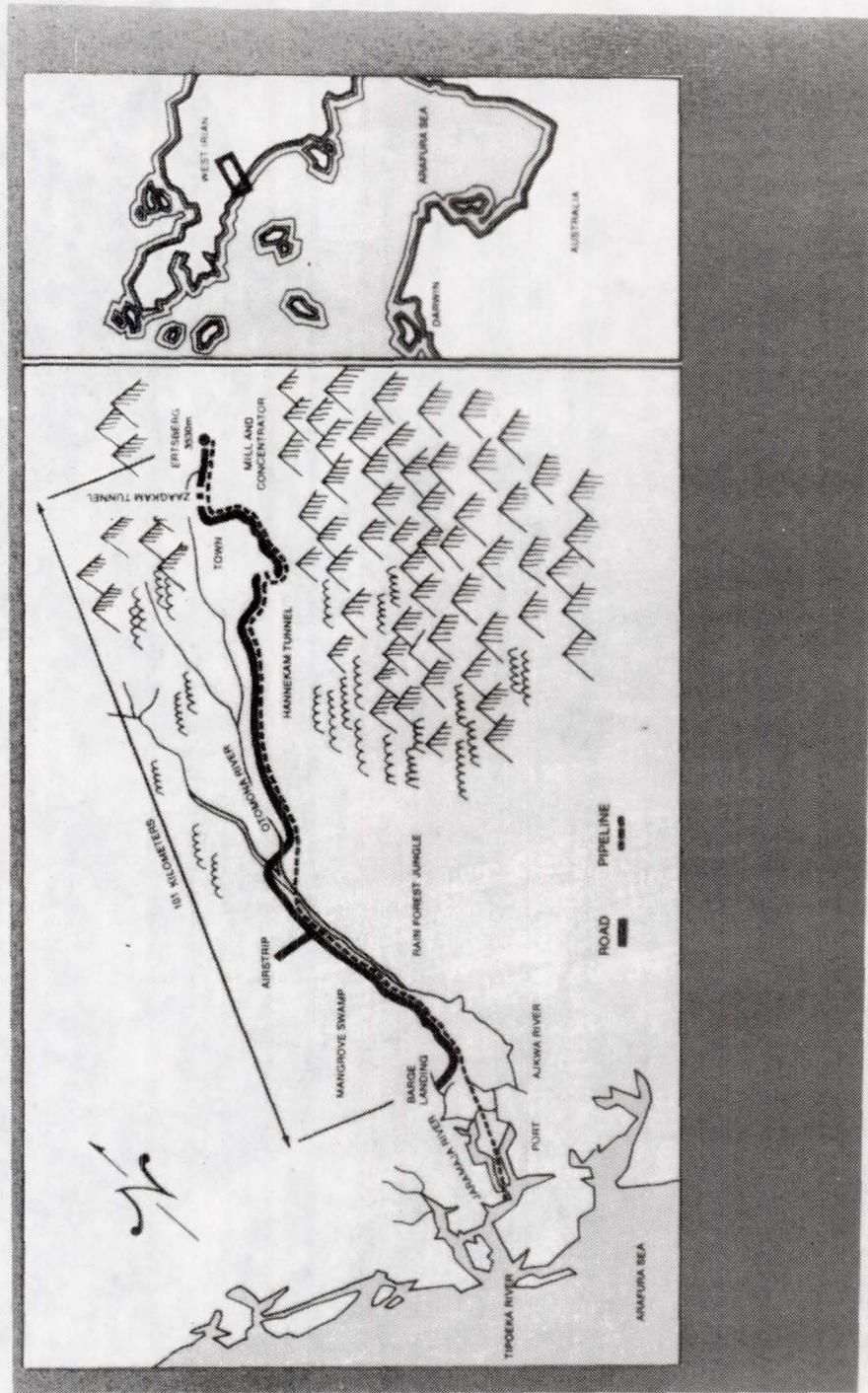


Figure 10(b). - Location of Ertsberg on West Irian island of Indonesia.

REMOTE MINING

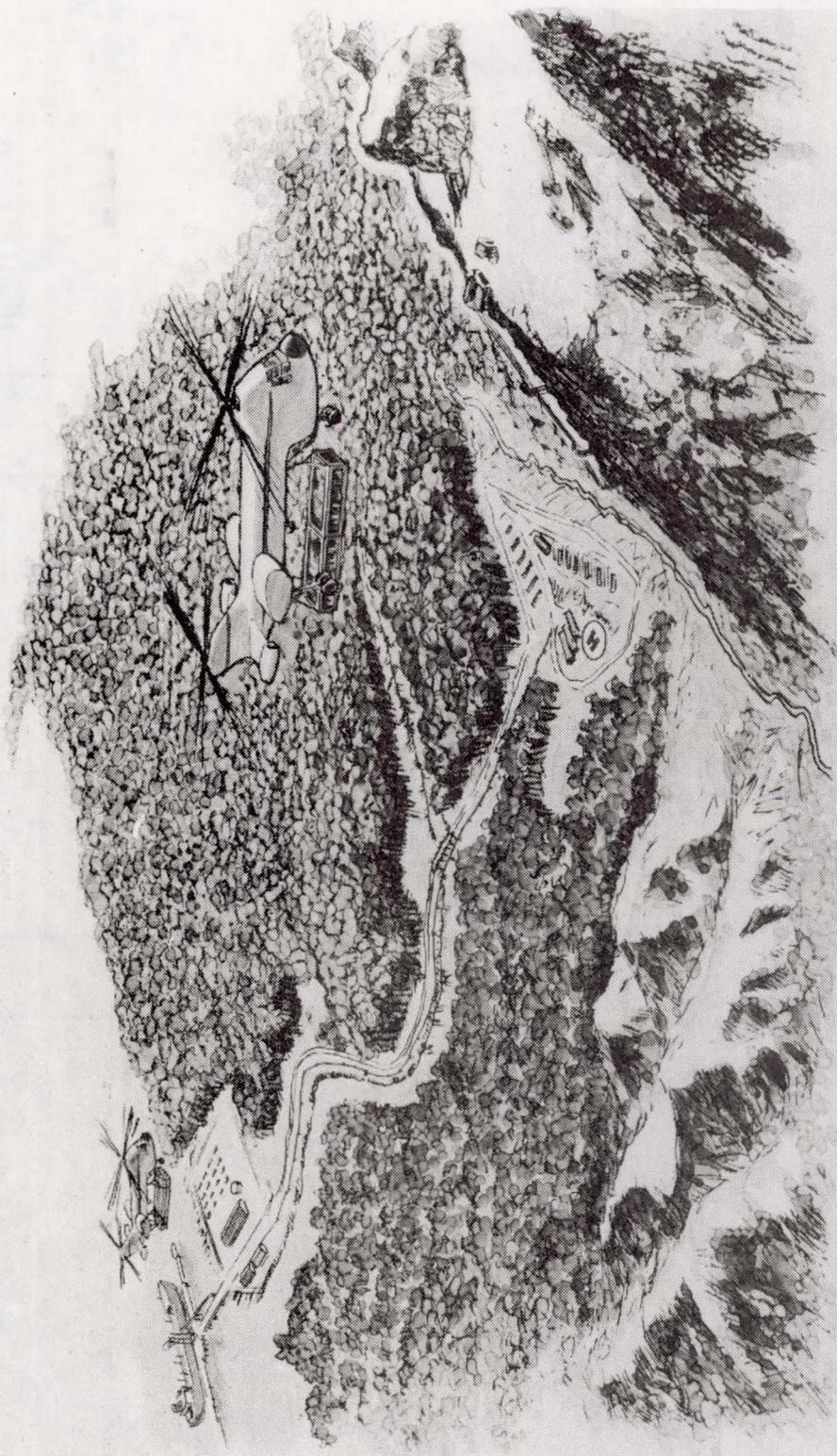


Figure 10(c). - Advanced helicopter concept used in remote mining.

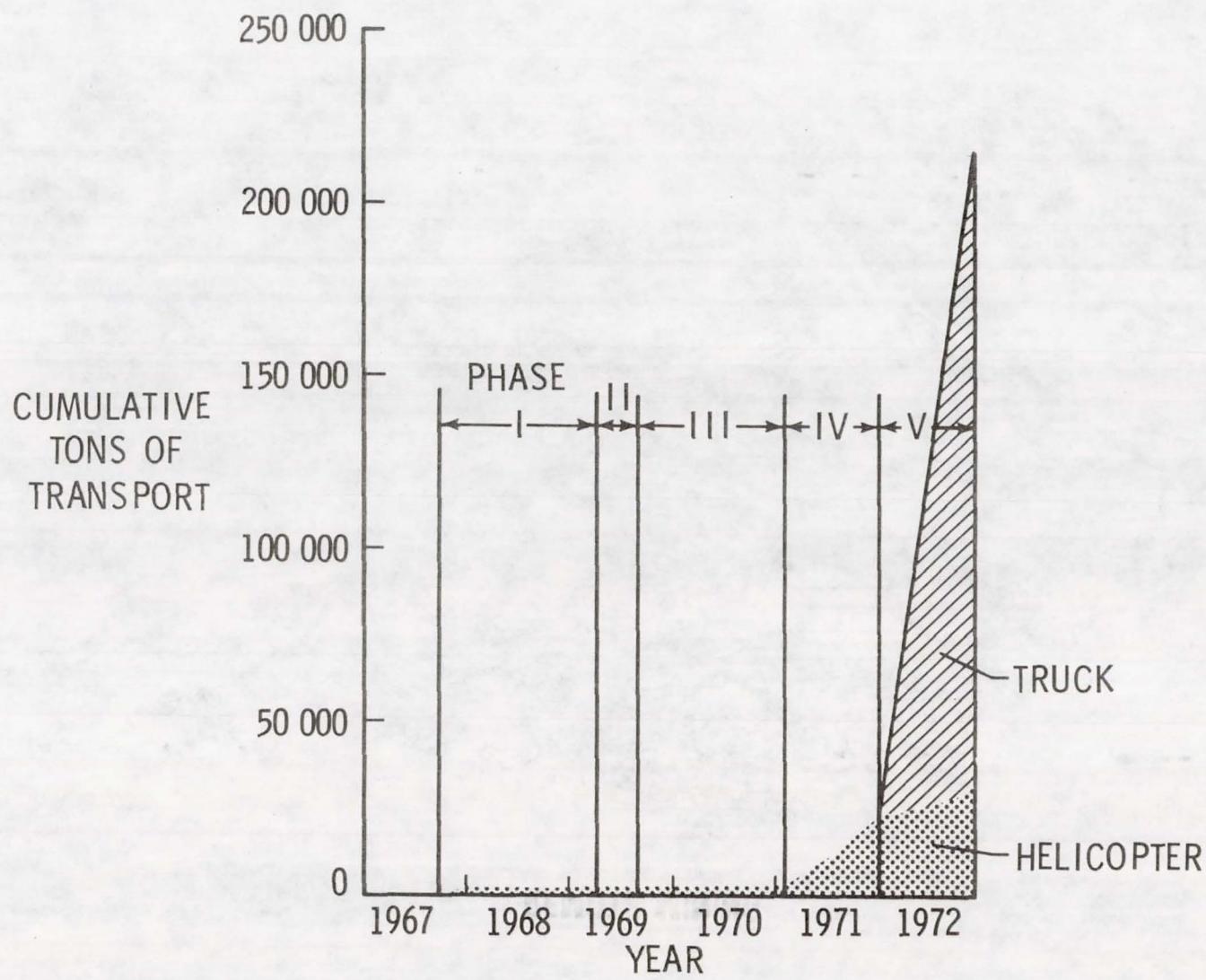


Figure 11. - Transport volume during Ertsberg development phases.

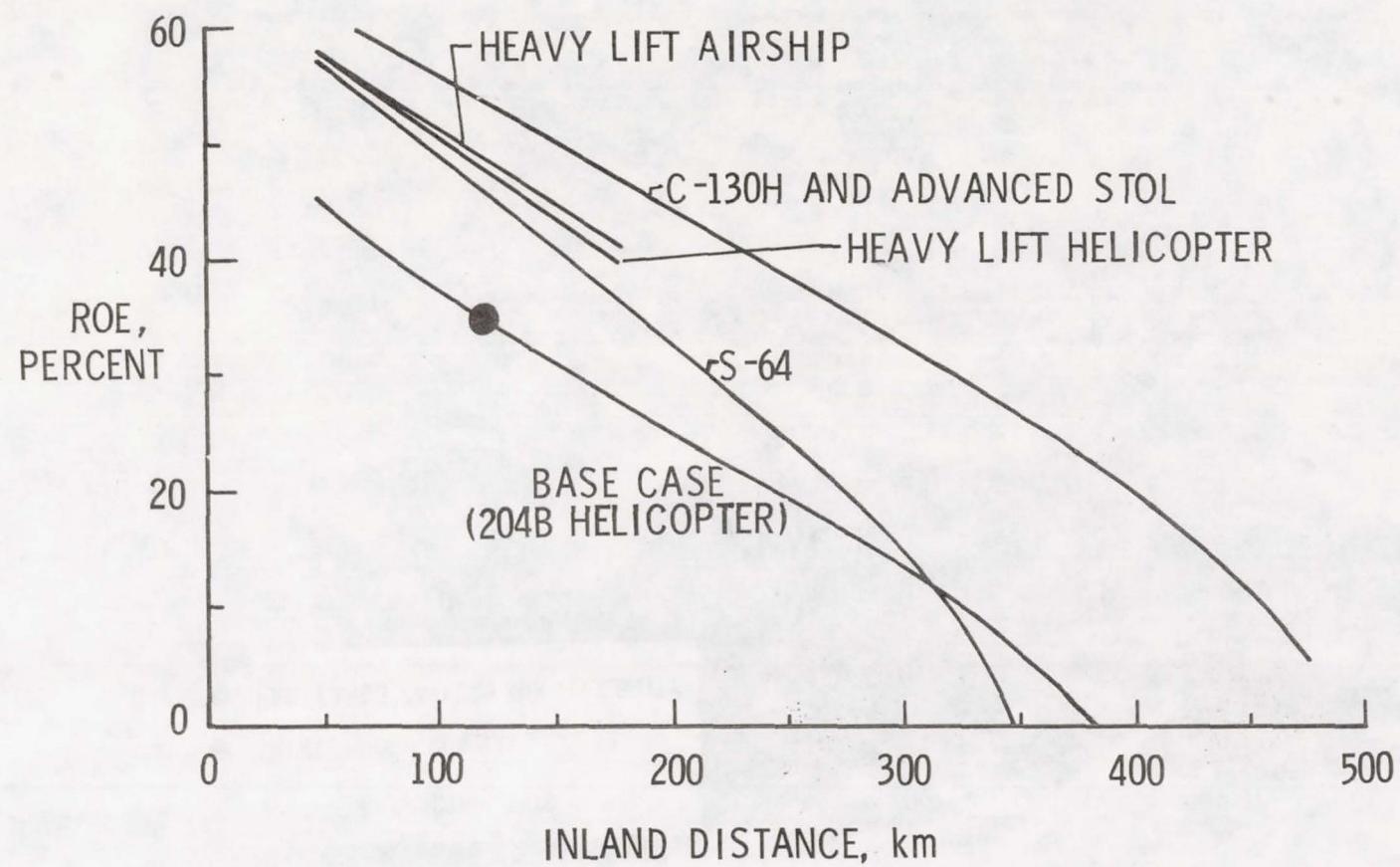


Figure 12. - Comparison of aircraft return on equity with distance.

CHARACTERISTICS

- SHORT / ROUGH RUNWAYS
- PAX / CARGO PAYLOAD MIX FLEXIBILITY



Figure 13. - Multipurpose short-takeoff-and-landing aircraft concept.

PAVED RUNWAY COMPARISON

	AIRPORTS	PAVED RUNWAYS
UNITED STATES	13770	5109
BRAZIL	1453	120
INDONESIA	67	14

- NATIONAL AIRPORTS
- INTERNATIONAL AIRPORTS

AIRPORTS IN BRAZIL



Figure 14. - Comparison of airport data.

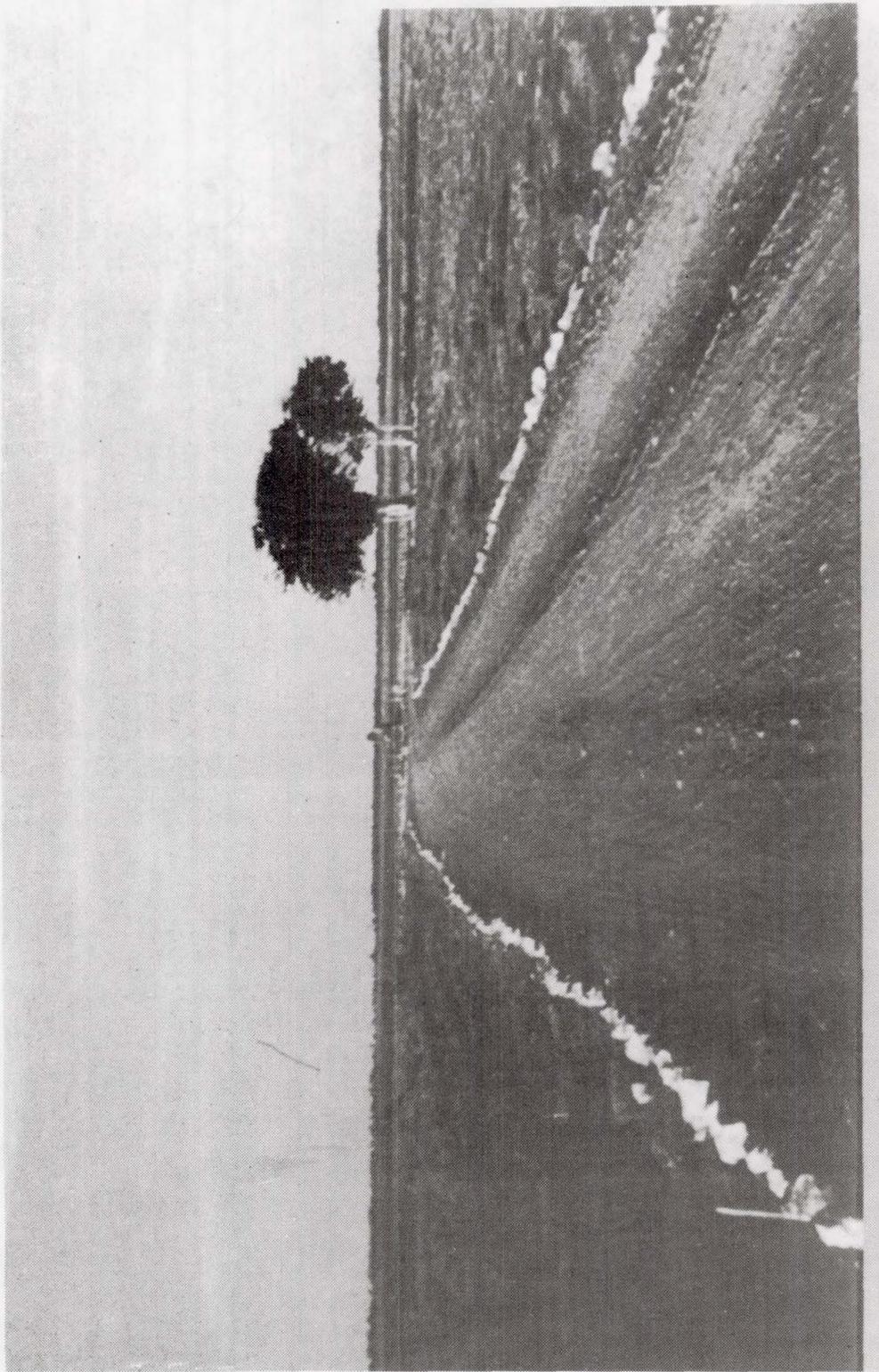


Figure 15. - Brazilian interior earth road.

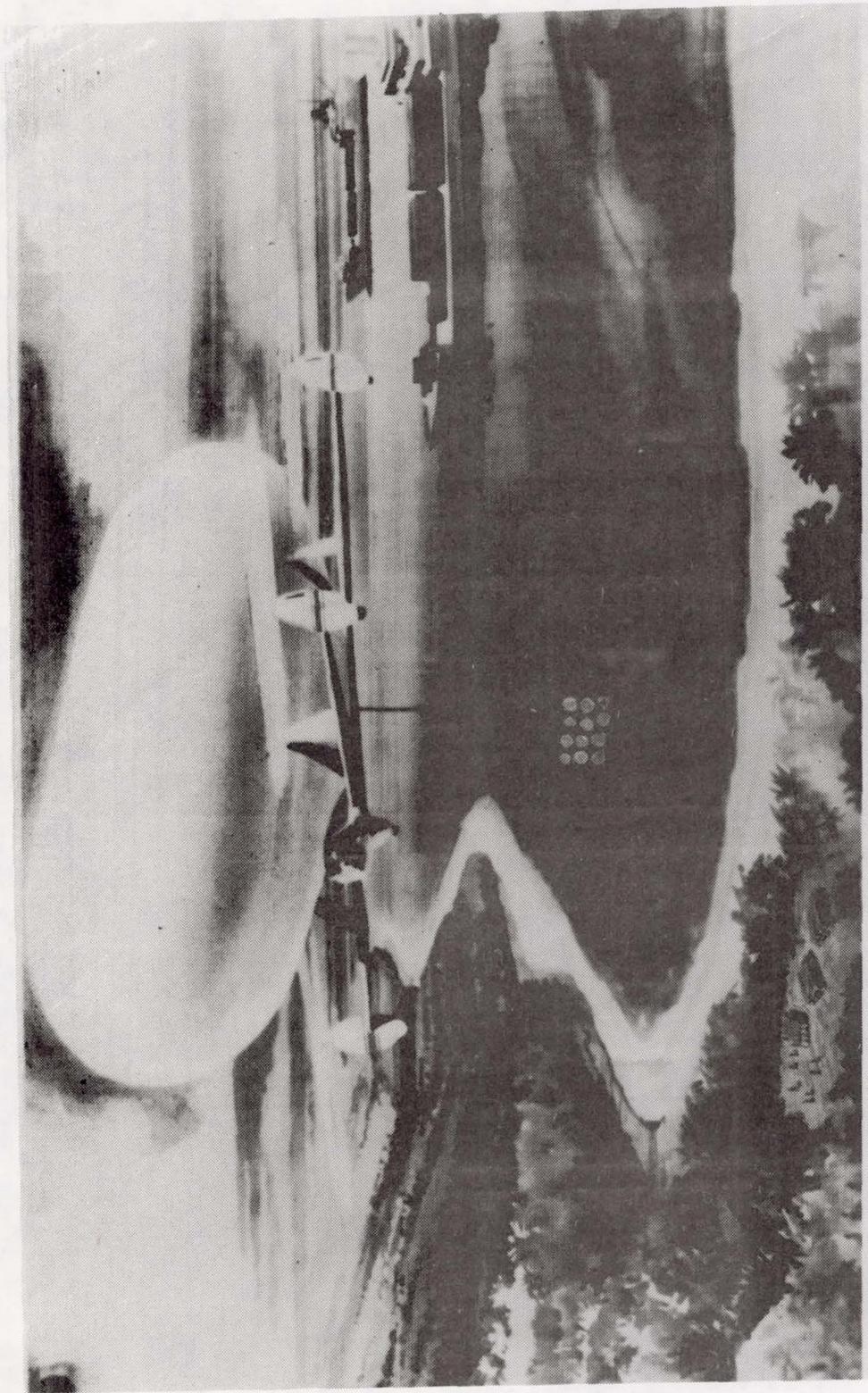


Figure 16. - Airship cargo concept for selective forestry application.

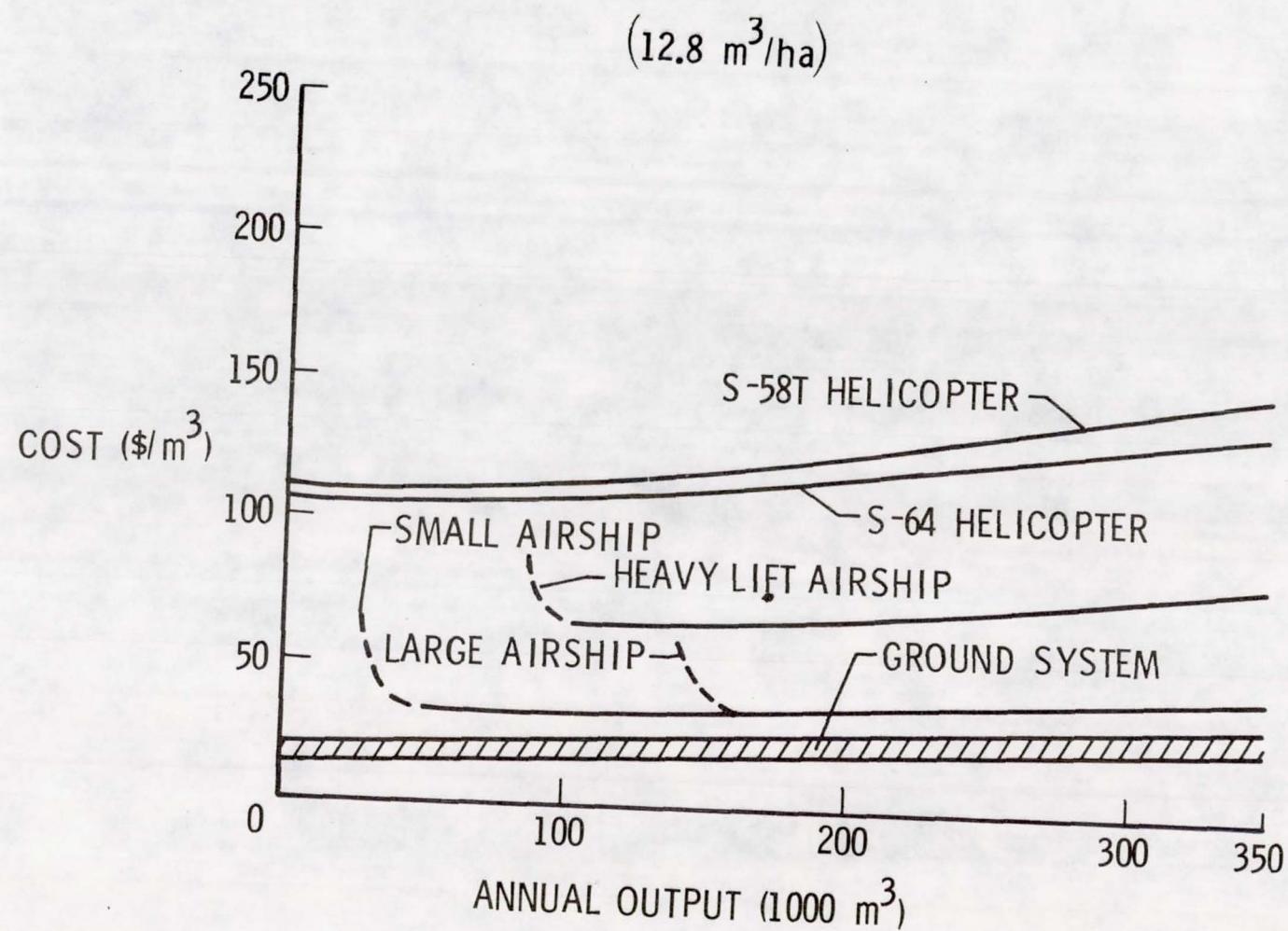


Figure 17(a). - Forestry economic results for ground versus air
(typical yield of 12.8 cu. m. per ha).

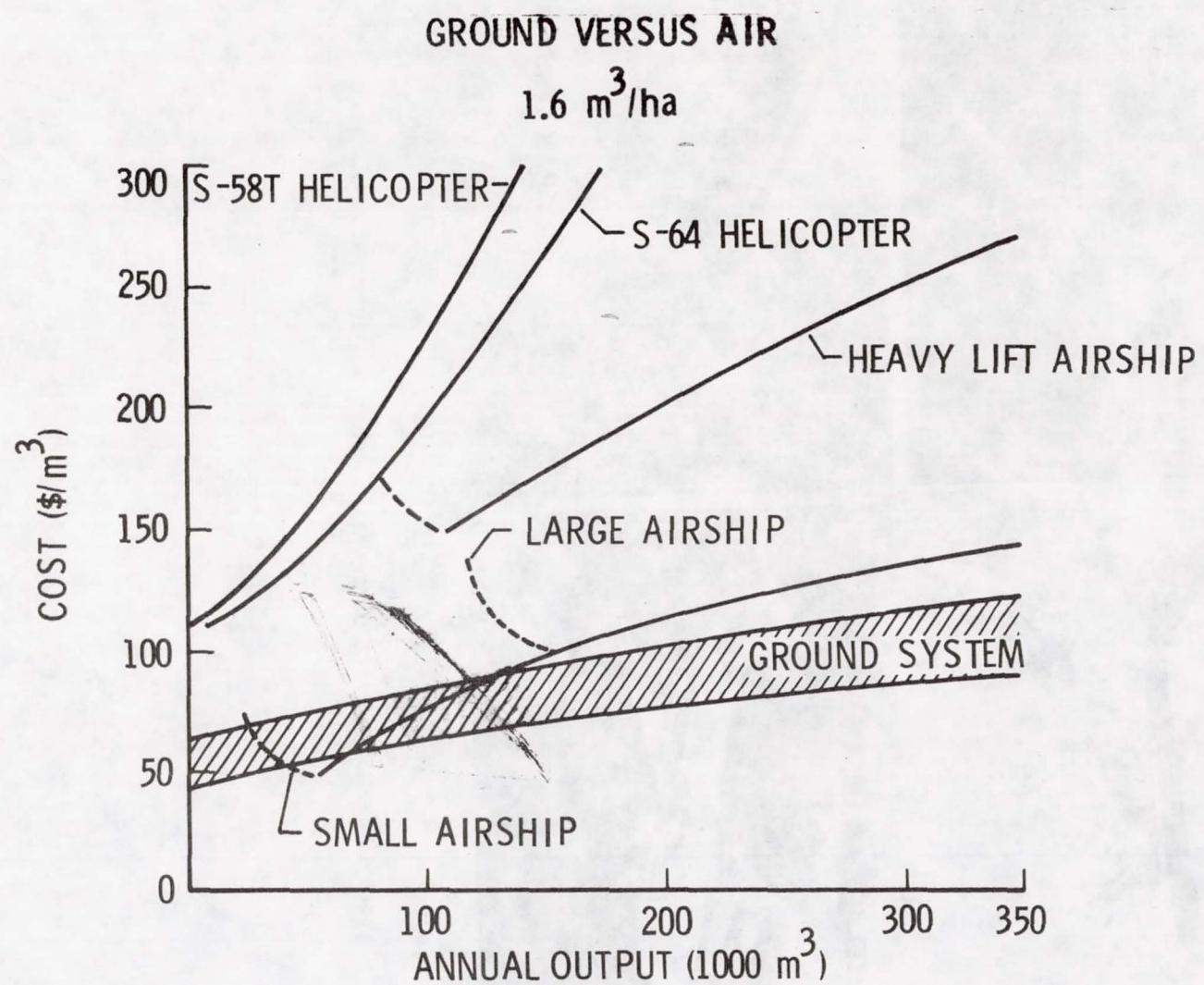
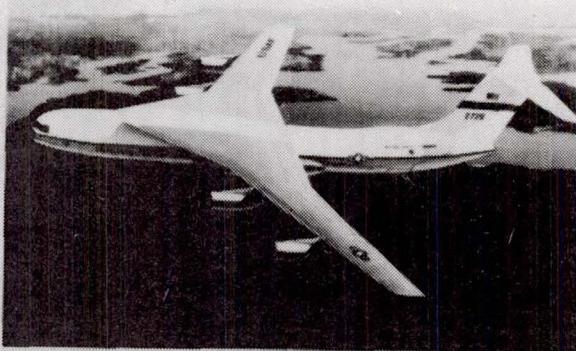


Figure 17(b). - Forestry economic results for ground versus air
(low yield of 1.6 cu. m. per ha.).

B 747F



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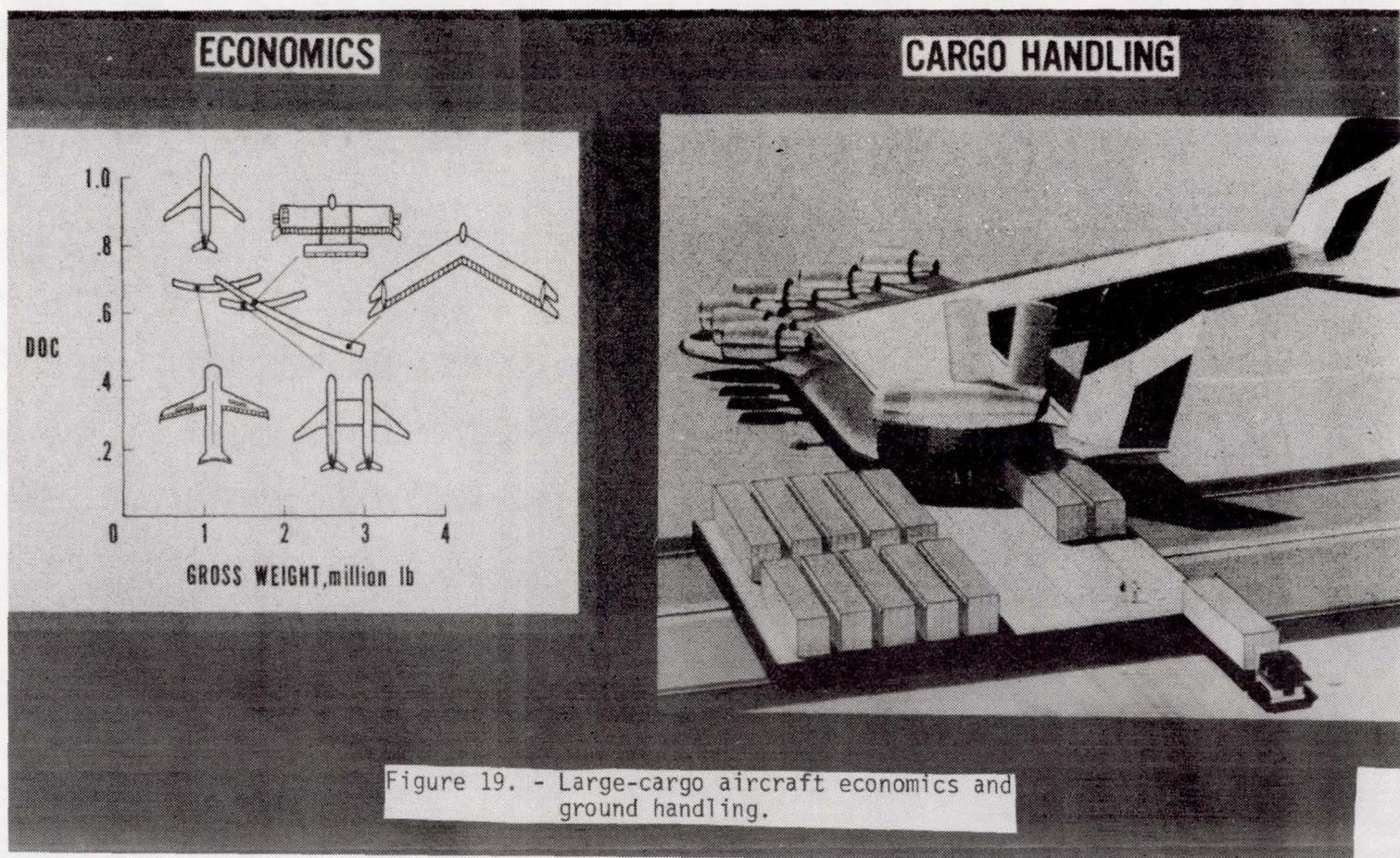
FUSELAGE LOADER



SPAN LOADER



Figure 18. - Large-cargo aircraft concepts for international trade.



	BRAZIL	INDONESIA
INTERNATIONAL ALL-CARGO	61	32
(LARGE CARGO AIRCRAFT)	(47)	(7)
DOMESTIC ALL-CARGO	42	13

Figure 20. - Projected all-cargo airplane market to year 2005 for Brazil and Indonesia.

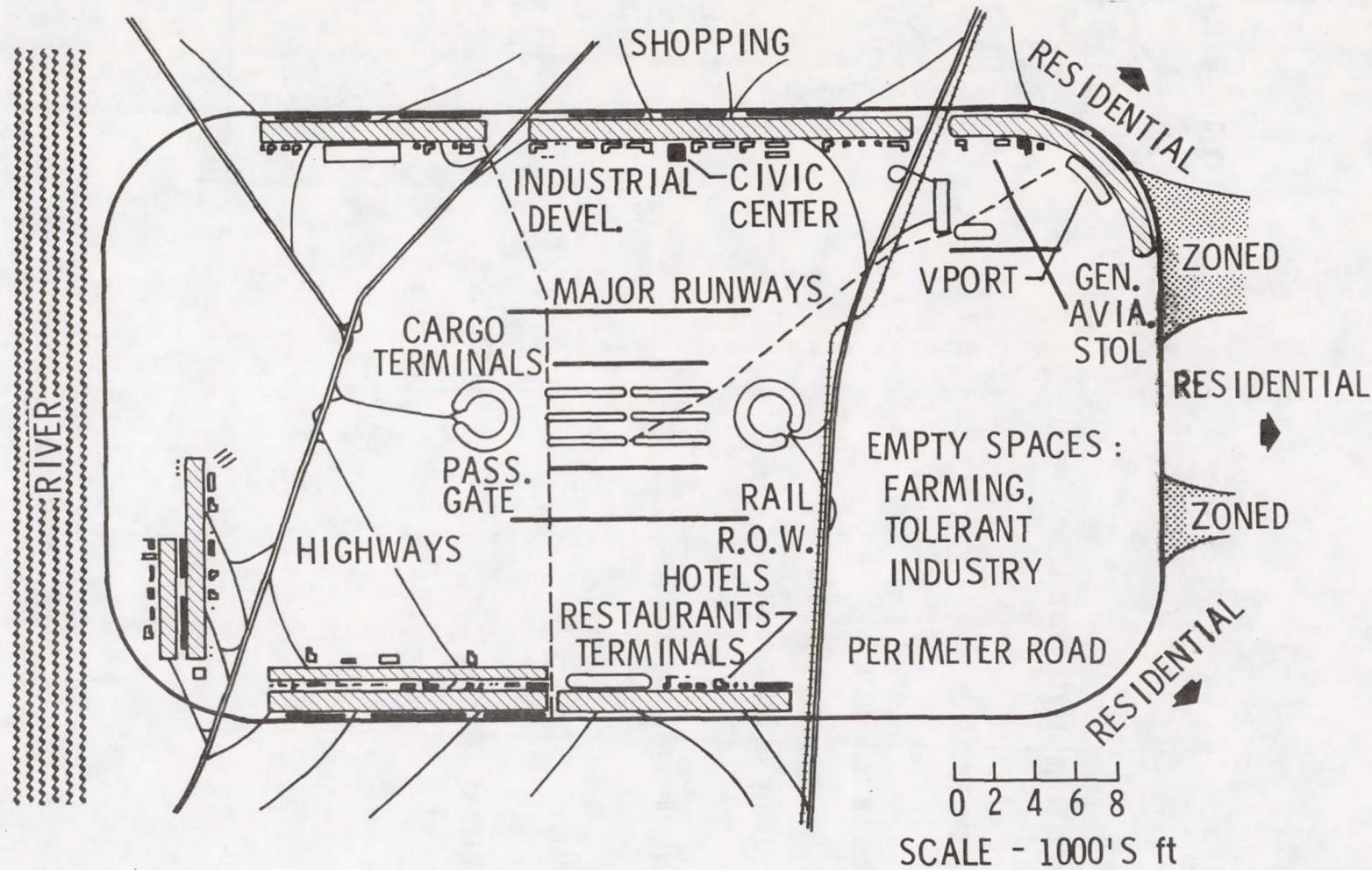


Figure 21. - Airport-industrial city concept.

- RAPID CARGO GROWTH POSSIBLE
- 140,000 POPULATION
- 1000 KM FROM BELEM
- EXTENSIVE BAUXITE DEPOSITS
- MANY HYDROELECTRIC SITES
- TIMBER
- LIVESTOCK

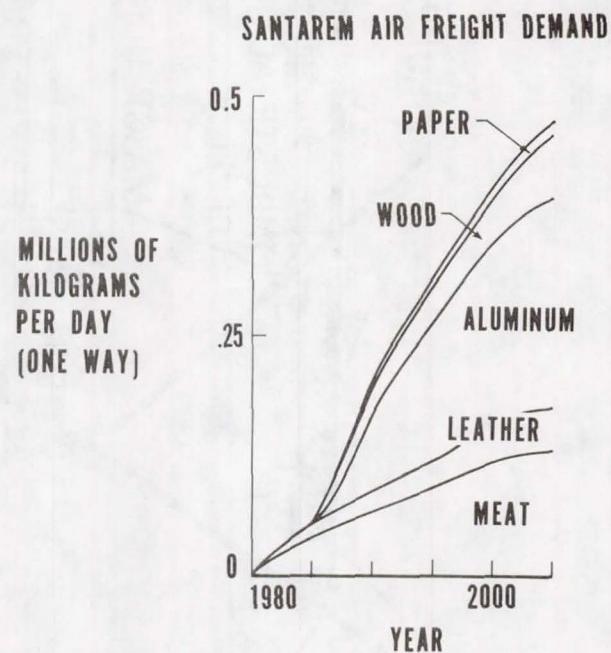
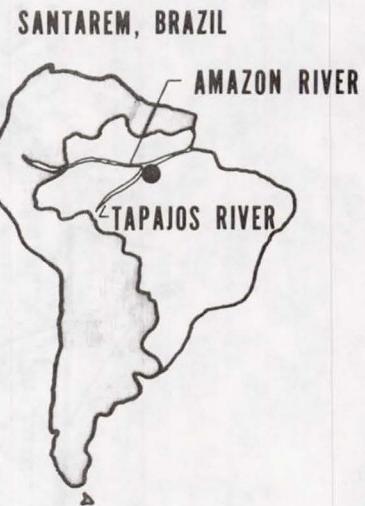
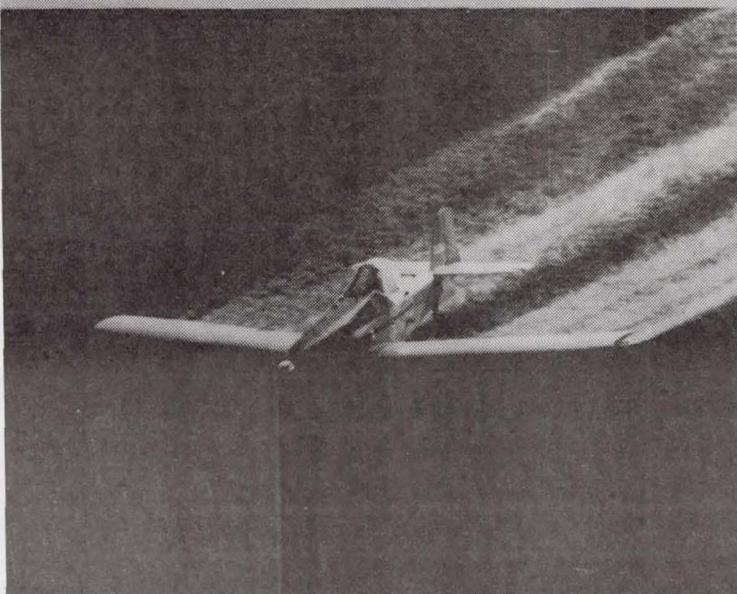


Figure 22. - Proposed airport-industrial city at Santarem, Brazil.

IMPROVED DISPERSEL PATTERNS

EXISTING



WINGLETS

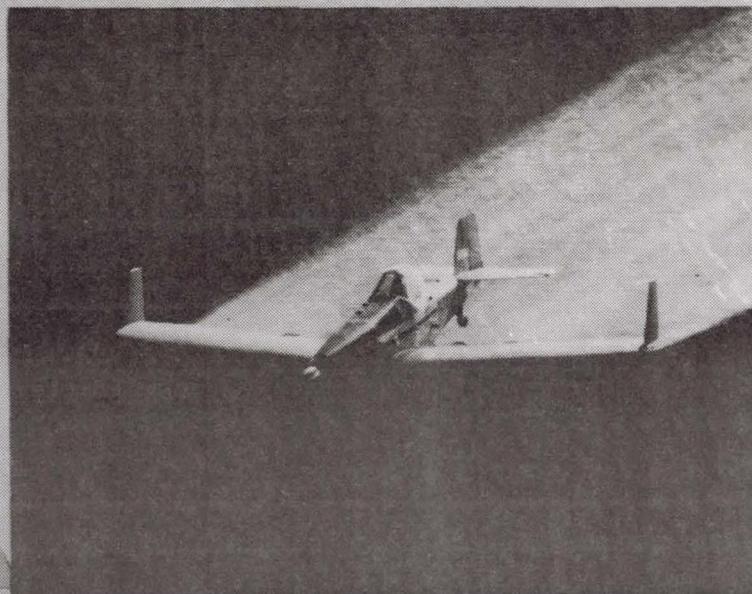


Figure 23. - Improved agricultural aircraft dispersal pattern.

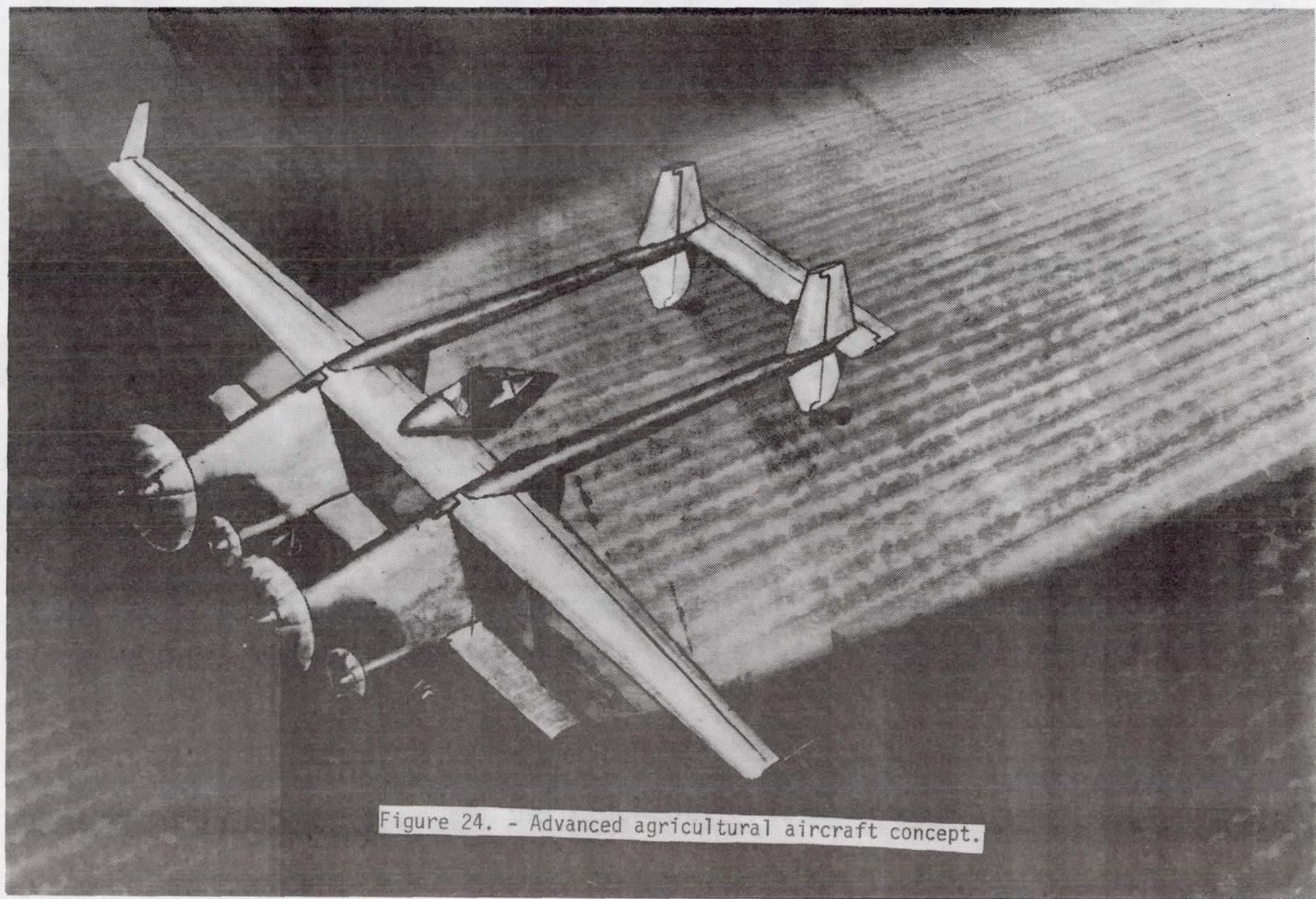


Figure 24. - Advanced agricultural aircraft concept.

AIRCRAFT TYPE	BRAZIL		INDONESIA	
	PRESENT	PURCHASES THRU 2005	PRESENT	PURCHASES THRU 2005
● DOMESTIC ALL-CARGO	3	42	1	13
● INTERNATIONAL ALL-CARGO (INCLUDES LARGE CARGO A/C)	4	61	0	32
● DOMESTIC PASSENGER	172	1390	97	904
● INTERNATIONAL PASSENGER	18	190	14	119
● GENERAL AVIATION	5394	67 100	270	6490

Figure 25. - Expected future aircraft fleet purchases in Brazil and Indonesia.

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16. Abstract <p>Air transportation concepts for movement of cargo in developing countries are reviewed using aircraft which may appear in the future. For certain industrial applications including mining and forestry, the relative costs of doing the job using different types of aircraft are compared with surface transportation systems. Two developing countries, Brazil and Indonesia, were taken as examples to determine what impact they might have on the aircraft markets of the future. Economic and demographic data on developing countries in general, and Brazil and Indonesia in particular, are reviewed. The concept of an industrial city in a remote area developed around an airport is discussed. It is noted that developing areas generally lack extensive surface transportation systems and that an air transportation system can be implemented in a relatively short time. A developing nation interested in rapid expansion may thus find the role of air cargo far more important than has been true in developed nations. Technological developments which may dramatically increase the performance of agricultural aircraft are also reviewed.</p>			
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